Supersonic Cruise Efficiency - Propulsion Tech Challenge Overview

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This presentation provides a brief overview of the research underway in the Cruise Efficiency – Propulsion technical challenge area of NASA's Fundamental Aeronautics Supersonics project. The research involves both computational and experimental efforts in the areas of Advanced Inlet Concepts, High Performance/Wide Operability Fan and Compressors, Advanced Nozzle Concepts and Intelligent Sensors/Actuators. The work consists of both internal NASA research and external efforts funded through the NASA Research Announcement process.

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Motivation

- In order to achieve economic viability, supersonic cruise civil aircraft need to achieve unprecedented levels of cruise efficiency. To achieve high efficiency, the propulsion system must be designed and optimized as an integrated system and installed in an optimal way on the airframe. This cruise efficiency must be preserved while 1) meeting stringent airport noise requirements at takeoff/landing and 2) minimizing the aircraft's sonic boom signature.

Objective

- Develop tools and propulsion technologies that will enable the design and analysis of:
  - High-efficiency, low-boom, and stable inlets
  - High performance/wide operability fans
  - High-performance, low-noise low-boom exhaust nozzles
  - Intelligent sensors and actuators for variable cycle engines.

Bulk of core turbomachinery work has been consolidated under the Subsonic Fixed Wing Project

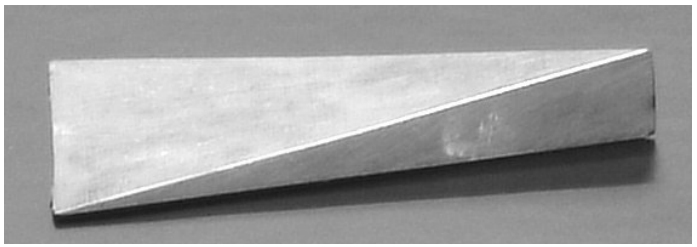
Research Elements

- Advanced Inlet Concepts
- High Performance/Wide Operability Fan and Compressor
- Advanced Nozzle Concepts
- Intelligent Sensors/Actuators

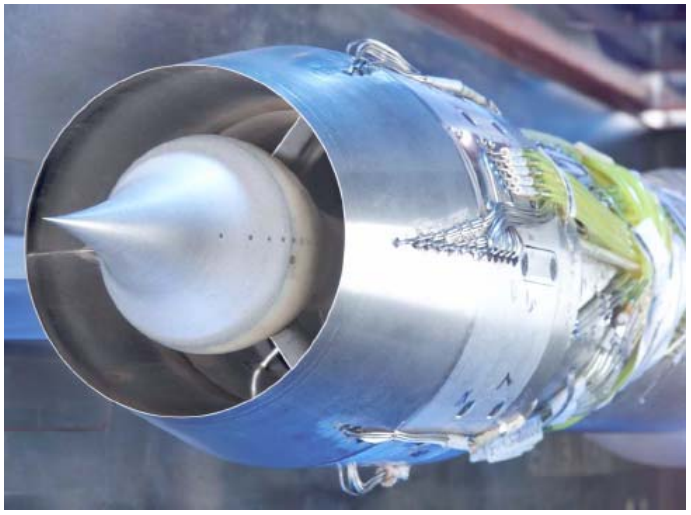
Advanced Inlet Concepts

- Supersonic Micro-Array Flow Control*
- Assess inlet-fan interactions
  - Computational modeling*
  - Validation experiment
    - Lockheed-Martin inlet
    - GRC 12” fan simulator (VIIPAR)
- Supersonic inlet design tools and methodologies
  - Starting FY08
  - Rehabilitate existing 2D codes
  - Develop 3D design codes for highly integrated inlets
  - Quick turnaround performance assessments

** Presentations to follow*



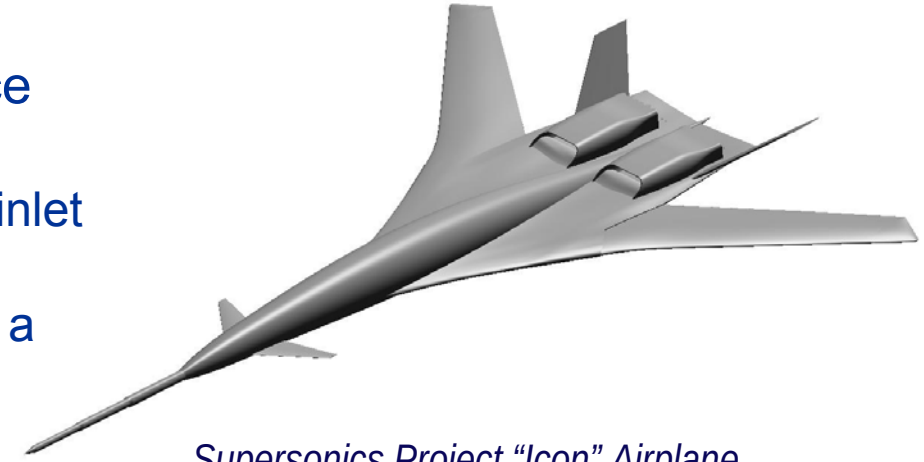
Micro-ramp flow control device for “bleedless” supersonic inlets



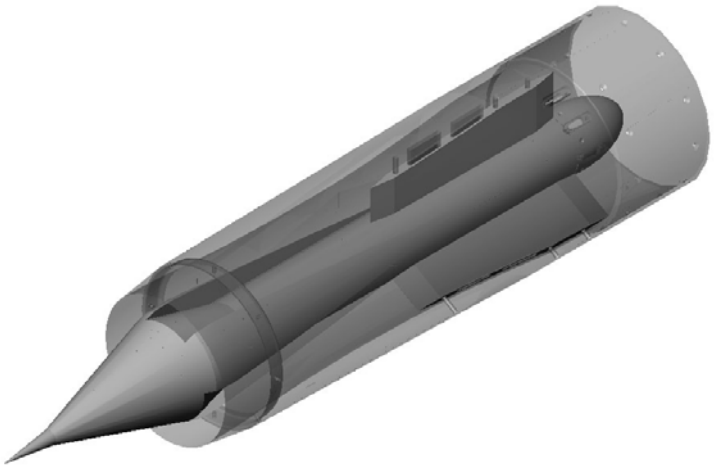
Relaxed supersonic compression inlet hardware tested in GRC 1’x1’ Supersonic Wind Tunnel

Advanced Inlet Concepts

- Low boom/high performance inlet technologies
  - Develop highly integrated inlet concepts
  - Use the “Icon” Airplane as a basis for development
  - Utilize new design tools
- Flight Test of Channeled Centerbody Inlet
  - Patented centerbody design allows large throat area variation through simple lightweight system
  - Developed by Techland Research under a NASA SBIR
  - Will be flight tested under supersonics program in FY09



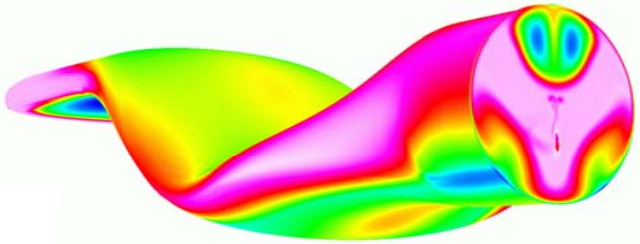
Supersonics Project “Icon” Airplane



Channeled Centerbody Inlet

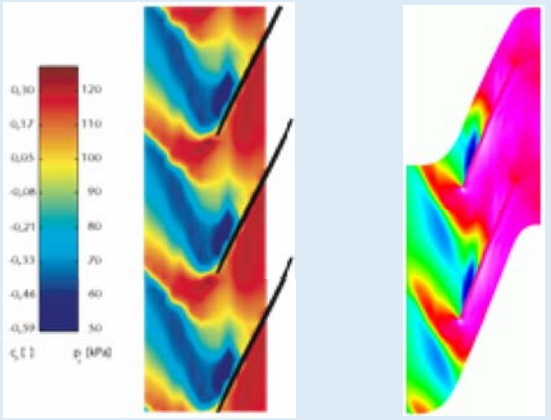
High Performance/Wide Operability Fan and Compressor

- Coupled inlet/fan modeling using large-eddy simulation (LES)
  - Component analysis - completed
    - Isolated Air Force UAV inlet
    - Isolated Fan
      - Darmstadt Rotor 1
      - Both on and off design
  - Coupled analysis
    - Air Force UAV inlet and Honeywell compressor
    - To be completed in FY08
  - H3D analysis code
    - Pressure based
    - 3rd order convective terms
    - Dynamic Smagorinsky sub-grid model



Analysis of U.S. Air Force UAV Inlet

Casing static pressure at off-design condition

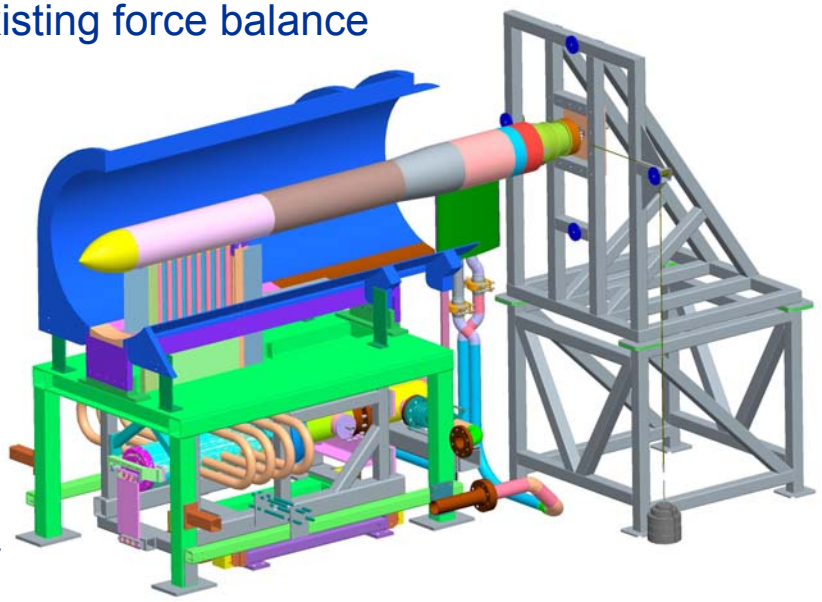


measurement **calculation**

H3D analysis of Darmstadt Rotor 1

Advanced Nozzle Concepts

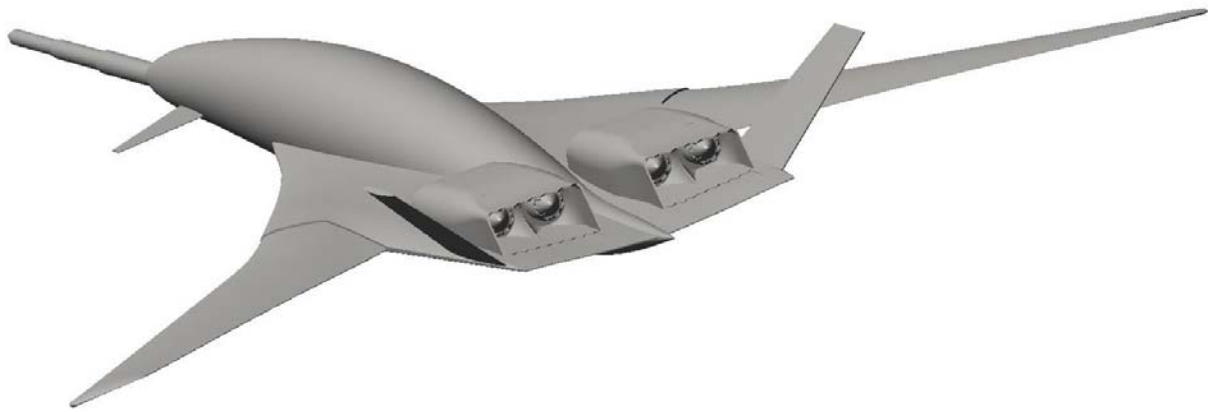
- State of the art nozzle force measurements
  - Upgrading NASA's capabilities for nozzle force measurements
  - Simultaneous force and noise measurements
    - High Flow Jet Exit Rig in the NASA Glenn Nozzle Acoustic Test Rig (NATR)
    - Modify, checkout and calibrate existing force balance
    - Work will be completed shortly
  - 6-component nozzle force measurements in supersonic wind tunnels
    - New task
    - Need force and moment measurements for highly integrated low-boom nozzle concepts
    - New balance being developed for GRC Jet Exit Rig
    - Rig used in GRC 9'x15', 8'x6' and 10'x10' wind tunnels



High Flow Jet Exit Rig, Force Balance and Calibration Hardware in NASA Glenn NATR

Advanced Nozzle Concepts

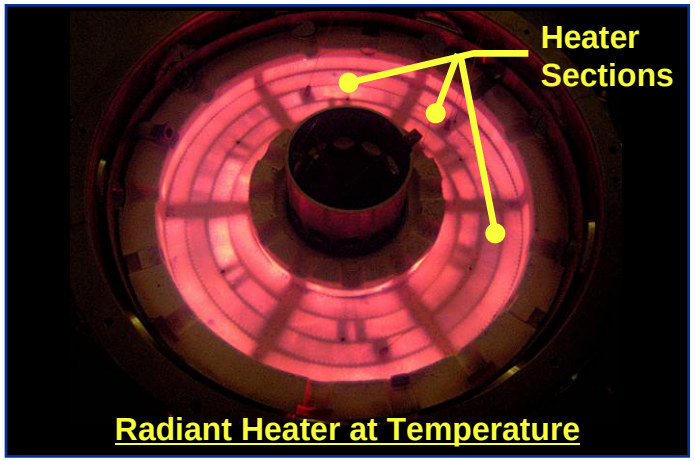
- Jet plume effects on sonic boom
  - New element for FY08
  - Assess effect of jet plume on sonic boom
  - Develop guidelines for nozzle shape, integration and operation for high-performance low-boom operation
  - Compliments LANCETS F-15 flight test examining jet plume effects on sonic boom



Intelligent Sensors/Actuators

- Microwave Tip Clearance Sensor
  - Use in closed-loop control of turbines and variable cycle engines
  - 5.8GHz Probe developed by Radatech/Vibro-meter under SBIR
  - Calibrate probe for making tip clearance measurements
  - Test probes in high pressure burner to evaluate performance in high temperature environment
- Active Clearance Control
  - ACC system demonstrated at 1140 F (1200 F goal)
  - Effective clearance 80% lower than industry reference threshold
  - Task not continuing due to manpower limitations

Microwave Tip Clearance Probe



Active Clearance Control Rig at 1140 F

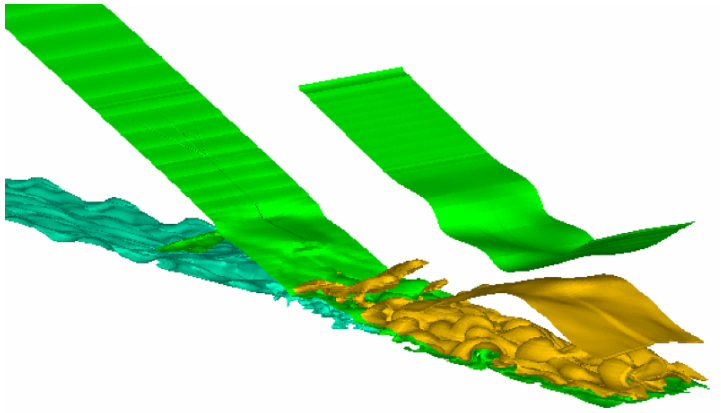
NASA Research Announcements (NRAs)

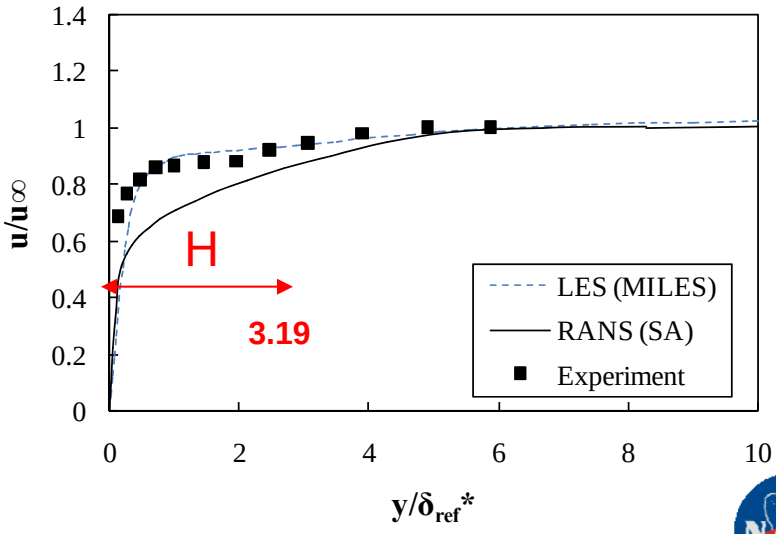
- Round 1 - Awarded Feb. 2007
  - "Shock Boundary Layer Interaction Flow Control with Micro-Vortex Generators using Large-Eddy Simulation", Eric Loth, University of Illinois
- Round 3 - Recently Selected
  - Inlet design and fabrication for a large-scale validation of micro-ramp flow control device
    - Aerodynamic design, mechanical design and fabrication of a supersonic inlet model for the purpose of validating micro-array flow control devices
    - 2 Awards
  - Inlet Bleed Modeling
    - Development of a model for porous bleed for use with Computational Fluid Dynamics (CFD) simulation of supersonic inlet flows.
    - 1 Award
  - Flow Angularity Probe
    - Develop a compact, high-response sensor for measurement of distortion in subsonic diffuser wind tunnel tests.
    - 1 Award

Shock Boundary Layer Interaction Flow Control with Micro-Vortex Generators using Large-Eddy Simulation

University of Illinois at Urbana-Champaign
PI: Eric Loth

- Develop high-order schemes in a production CFD code (Wind) for LES of Shock Boundary-Layer Interactions
- Examine solution sensitivity to
  - numerical scheme
  - grid/time-step resolution
- Investigate μ-ramps effect on
  - Oblique Shock Boundary Layer Interactions (M∞ ca. 2.5)
  - Normal Shock Boundary Layer Interactions (M∞ ca. 1.4)
  - NSBLI Interactions with Downstream Diffuser





Partnerships

- Micro-array flow control for shock-wave boundary-layer interactions
  - U.S. Air Force Research Laboratory (AFRL), Memorandum of Understanding
  - Sharing of computational results, experimental data and design of experiments methodologies
- Active inlet flow control/high cycle fatigue
  - Lockheed-Martin, Space Act Agreement
  - L-M provided inlet hardware for testing on GRC fan simulator (VIIPAR rig)
- Testing of the Relaxed Supersonic Compression Inlet
  - Gulfstream, Space Act Agreement
  - Gulfstream provided inlet hardware for testing in GRC 1'x1' Supersonic Wind Tunnel
  - Shared CFD analysis

Technical Presentations

"Rapid Calculations of Three-Dimensional Inlet / Fan Interaction"
Dr. Rod Chima
NASA Glenn Research Center

"Application of Microramp Flow Control Devices to an Oblique Shock Interaction"
Ms. Stefanie Hirt
NASA Glenn Research Center